

The invention relates to a mini-fan. Such fans are also referred to as miniature or subminiature fans.

Mini-fans serve, for example, to cool processors in computers, for the cooling of small equipment items, etc. and have very small dimensions. For example:

- fans of the ebm-papst 250 series have dimensions of 8 x 25 x 25 mm;
- those of the ebm-papst 400F series, dimensions of 10 x 40 x 40 mm;
- those of the ebm-papst 400 series, 20 x 40 x 40 mm; and
- those of the ebm-papst 600 series, 25 x 60 x 60 mm.

The power consumption of such fans is 0.4-0.6W for the 250 series, 0.7-0.9 W for the 400F series, and 0.9-3.4 W for the 400 and 600 series. The weight is, for example, approximately 5 (five) grams for the 250 series, between 17 and 27 g for the 400/400F series, and approximately 85 g for the 600 series.

With fans of this miniature size, which must be very inexpensive, it is important to make assembly as simple as possible in order to enable a high level of automation during manufacture. Only extensive production automation additionally makes possible uniform quality in such fans, which is a prerequisite for a long average service life.

A complicating factor with such mini-fans is furthermore that their components, entirely comparable to those of a mechanical watch mechanism, are very delicate and therefore not robust. The rotor shaft, for example, is often only as thick as a knitting needle, and can therefore easily be bent if handled carelessly, rendering the fan unusable. This danger exists in particular during the assembly of such a mini-fan, for example when it must be acted upon by a force for assembly purposes.

An object of the invention is therefore make available a novel mini-fan. According to the invention, this object is achieved by the subject matter of Claim 1.

What is thereby achieved, with simple means, is a secure, liquid-tight join between the bearing tube and the closure arrangement. Because the invention makes it possible to assemble the internal stator while it is still separate from the rotor, and because the internal stator is a substantially more robust component than the external rotor, the danger of damage during the assembly operation is substantially reduced.

In the context of a mini-fan according to the present invention, it is therefore possible first to assemble the internal stator; and once the latter has been, for example, soldered in place on a circuit board, the rotor can then very easily be installed and at the same time secured, by way of the at least one resilient securing member, against being inadvertently pulled out.

Further details and advantageous refinements of the invention are evident from the exemplifying embodiments, in no way to be understood as a limitation of the invention, that are described below and depicted in the drawings, and from the additional claims. In the drawings:

FIG. 1 is a greatly enlarged longitudinal section through a mini-fan according to a preferred embodiment of the invention; for illustration only, a one-centimeter length is indicated for comparison, although the size of the fan can of course fall within the limits typical for such miniature and subminiature fans;

FIG. 2 is an even greater enlargement to explain the lubricant circulation in the bearing arrangement with plain bearing that is depicted;

FIG. 3 depicts one possible variant for connecting the stator winding of the external-rotor motor according to FIGS. 1 and 2 to a circuit board;

FIG. 4 is a very greatly enlarged longitudinal section through a mini-fan according to a second embodiment of the invention;

FIG. 5 shows a portion of FIG. 4 at location V therein;

FIG. 6 is a section according to a first alternative, looking along line VI-VI of FIG. 4;

FIG. 7 is a section according to a second alternative, looking along line VI-VI of FIG. 4;

FIG. 8 is a section analogous to FIG. 4, but after the mating of the internal stator and circuit board;

FIG. 9 is a depiction analogous to FIG. 8, but before the mating of the internal stator and external rotor; and

FIG. 10 is a depiction analogous to FIG. 9, but after the mating of the internal stator and external rotor; the external rotor is secured on the internal stator against being pulled out, and the lower (in FIG. 10) side of the bearing support tube is closed off in liquid-tight fashion.

FIG. 1 shows, at very greatly enlarged scale, a longitudinal section through a mini-fan 16 associated with which, for driving thereof, is an external-rotor motor 20. Fan 16 can have, for example, dimensions of 10 x 30 x 30 mm. Motor 20 has an external rotor 22 having a rotor cup 24, preferably made of a thermally conductive plastic, on whose outer periphery fan blades 26 are provided. A magnetic yoke 27 made of soft iron is mounted in rotor cup 24, and on the yoke's inner side is a radially magnetized rotor magnet 28 that can be magnetized, for example, with four poles. The outside diameter of external rotor 22 can range, for example, from approximately 14 to approximately 35 mm.

Fan 16 is depicted here as an axial fan, but the invention is equally applicable, for example, to diagonal fans and to radial fans.

Rotor cup 24 has at its center a hub 30 in which is mounted, in thermally conductive fashion by plastic injection molding, a correspondingly shaped upper shaft end 32 of a rotor shaft 34 whose lower, free end is labeled 35.

Radial support of shaft 34 is provided by a plain bearing 36 that preferably is implemented as a sintered bearing. Alternatively in the context of the invention, in order to achieve a particularly long service life, shaft 34 can also be supported using rolling bearings. Plain bearing 36 is mounted by being pressed into the interior of a constriction 37 of a bearing tube 38. Bearing tube 38 is preferably manufactured from steel, brass, or another suitable metal, or if applicable also from a plastic. Provided at its lower end is a radial projection in the form of a flange 39, which serves for the mounting of fan 16 and here extends approximately perpendicular to rotation axis 41 of rotor 22. Internal stator 44 of motor 20 is mounted on the outer side of bearing tube 38 by being pressed on.

Constriction 37 has a substantially cylindrical inner side 40 (FIGS. 2 and 3) whose surface is particularly carefully machined, while the remainder of the inner side of bearing tube 38 needs to be only roughly machined. Corresponding to constriction 37, sintered bearing 36 has a bulging portion 42 having a diameter that corresponds approximately to the diameter of inner side 40 and is dimensioned so that a tight fit results upon assembly in inner side 40. Within portion 42, sintered bearing 36 has a portion 43 (FIG. 2) having an enlarged diameter, at which the sintered bearing does not make contact against shaft 34. This prevents sintered bearing 36 from being excessively radially compressed in the event of an accumulation of unfavorable tolerances, which might make it impossible to insert shaft 34.

A lower plain bearing portion 48 is located below portion 43, and an upper plain bearing portion 50 is located above portion 43 (cf. FIG. 2). It has been found that specifically in mini-fans with their small dimensions, very reliable support of shaft 34, and a correspondingly long service life for motor 20, are thereby obtained.

Stator 44 has, in the usual fashion, a lamination stack 45 that is injection-embedded in a coil former 46 onto which a winding (not depicted) is wound. Alternatively, the stator could also be implemented as a claw-pole stator, a design that is frequently used in small fans of this kind. The embodiment depicted nevertheless represents a preferred embodiment.

Shaft 34 has, at its free end region 35, an annular groove 58 into which elastic latching hooks 60 are latched after assembly. These have a smaller axial extension than annular groove 58, and their function is principally to secure rotor 22 against being inadvertently pulled off. As shown with particular clarity in FIG. 3, latching hooks 60 do not rest against shaft 34 at any point.

Latching hooks 60 are implemented integrally with a cover (latching cover) 62, and are located on a lubricant repository 64 at whose bottom is a depression 66 in which a tracking cap 68 of shaft 34 rotates. Depression 66 can also be referred to as a "tracking cap cup." Depression 66 and tracking cap 68 together form an axial bearing for shaft 34.

Fan 16 has an outer air-directing housing 74 that is joined via struts 76 (of which only one is indicated) to flange 78 that carries motor 20. Flange 78 has at its center an opening 80 that serves to receive and guide bearing tube 38. A flange-like enlargement 39 of bearing tube 38 is guided in a corresponding opening 84 of flange 78. Bearing 38 is epilam-coated at those points where it is guided in flange 78, in order to modify its surface tension in such a way that very little or no lubricant can migrate outward from repository 64 along that surface.

Opening 84 has a larger diameter than opening 80. Adjoining opening 84, as depicted in FIG. 3, is an opening 86 having an even larger diameter, and adjoining that a very flat opening 88 having a still larger diameter.

Latching cover 62 is implemented in complementary fashion to openings 84, 86, and 88, and is preferably guided in the innermost opening 84, in particular with a sliding fit. Its lower surface 90 (FIG. 3) serves as the identification plate, is substantially planar, and aligns with underside 92 at the outer periphery of flange 72. An identification plate can be adhesively bonded onto underside 90, 92, or that underside is marked directly, for example by laser marking.

Both flange 78 and cover 62 are manufactured from a suitable hard thermoplastic, for example PA 6.6, that can be welded by means of a laser 96 (FIG. 1). Latching cover 62 is preferably light in color, e.g. white, to allow easy imprinting. It has a transmissivity suitable for a focused laser radiation 98 proceeding from a laser 96, which radiation is focused onto points 100, 102 (FIG. 3) on either side of the outer boundary of opening 86.

Before welding, as shown in FIG. 1, a glass plate 104 is pressed from below against cover 62 with a force  $F$ , and fan 16 is then rotated beneath laser 96 in order to obtain a continuous, liquid-tight weld seam at points 100, 102. Alternatively, fan 16 can be stationary and laser 96 can be rotated. Glass plate 104 is pressed on in order to prevent deformations of cover 62 upon welding.

The weld seam at points 100, 102, which is not visible from outside, produces a liquid-tight join between flange 78 and cover 62, so that lubricant 110 (FIG. 2) in the interior of bearing tube 38 is prevented from emerging downward out of bearing tube 38.

Above flange 78, internal stator 44 is pressed onto outer side 106 (FIG. 3) of bearing tube 38. This outer side is cylindrical, but if applicable can taper slightly toward the top, i.e. can be slightly conical. Stator 44 is preferably pressed on until coil former 46 is resting against the upper side of flange 78.

FIG. 2 schematically shows the circulation of the lubricant (labeled 110 and indicated by dots) in bearing tube 38. It rises along shaft 34 as far as hub 30, which has at its lower (in FIG. 2) end an undercut 112 that causes lubricant 110 to be thrown outward.

Bearing tube 38 also has a undercut 114 at its upper end on the inner side, preventing lubricant 110 from leaking out of fan 16 when the latter is in a tilted position. For this reason, gap 116 between bearing tube 38 and rotor 22 is also very narrow and is dimensioned in the manner of a capillary gap. Lubricant 110 thrown outward from undercut 112 flows along the inner wall of bearing tube 38 down to sintered bearing 36, and through the latter farther down into reservoir 64. The result of this is that a sufficient supply of lubricant 110 is always present in reservoir 64 and in its depression 66; this is also particularly important for low-noise starting at low temperatures.

FIG. 3 shows the join between the winding (not depicted) of stator 44 and a circuit board 120 that is located between internal stator 44 and flange 78. Provided for this purpose on coil former 46 are pegs 122 made of plastic, only one of which is depicted in FIG. 3. A connecting wire 124 of the stator winding (not depicted) is wound around peg 122 and the peg is then inserted through an opening 126 of circuit board 120 and soldered, by means of solder 128, to a printed circuit on circuit board 120. Also located on circuit board 120 is a rotor position sensor (not depicted), e.g. a Hall sensor.

It is of course also possible to mount a wire pin 132 in coil former 46, and to make the join by way of such wire pins. One such wire pin 132 is indicated in FIG. 3 with dashed lines. The second exemplifying embodiment shows this type of solution.

Circuit board 120, which is populated on both sides with electrical components 134, is retained on stator 44 by way of either plastic pegs 122 or wire pins 132. At the center, the board has an opening 134 with which it surrounds an axial projection 136 of hub 78.

## ASSEMBLY

Firstly, sintered bearing 36 is pressed from below into bearing tube 38, specifically into its optimally machined inner side 40, i.e. into constriction 37. Bearing tube 38 is then pressed into opening 80 of housing flange 78, and latching cover 62 is set in place and welded to flange 78 in the manner described, with the result that bearing tube 38 is joined in liquid-tight fashion to flange 78.

Stator arrangement 44 is joined to circuit board 120 in the manner described, and then pressed onto bearing tube 38.

Fan wheel 22 is equipped with a ring magnet 28, and the latter is magnetized in the desired fashion. Opening 66 for tracking cap 68 is filled with grease, and shaft 34 is inserted through sintered bearing 36 (previously impregnated with lubricant) until retaining prongs 60 snap into annular groove 58 and make it impossible to pull rotor 22 out.

Because magnet 28, as depicted in FIG. 1, is not arranged symmetrically with respect to stator laminations 45 in terms of the axial direction of motor 20, but instead is offset upward with respect to them, a magnetic force  $F_m$  (FIG. 1) acts on rotor 22 in a downward direction, pressing tracking cap 68 into depression 66.

Mini-fan 16 according to FIGS. 1 to 3 has a relatively large overall height, which limits its application possibilities. The fan according to a second exemplifying embodiment of the invention that is presented below allows for an extraordinarily flat design. For the second exemplifying embodiment according to FIGS. 4 to 10, the same reference characters are used for identical or identically functioning components but are incremented by 200, i.e., for example, 220 in the second exemplifying embodiment instead of 20 in the first.

FIG. 4 shows a circuit board 217 on which a mini-fan 216 (FIG. 10) is mounted in order to cool hot components that are located on circuit board 217.

Electronic components (e.g. resistors, power transistors, microprocessors, and the like) that become particularly hot during operation are often located on such a circuit board, and they form so-called hot spots thereon that require active cooling. A mini-fan 216 such as the one depicted in FIG. 10 makes such active cooling possible, and requires very little space to do so.

As shown in FIG. 10, mini-fan 216 has an external rotor 222 having a rotor cup 224 on whose outer periphery fan blades 226 are provided. A magnetic yoke 227 made of soft iron is mounted in rotor cup 224, and located on the yoke's inner side is a radially magnetized rotor magnet 228 that can be magnetized, for example, with four poles. Outside diameter  $D$  (FIG. 10) of external rotor 222 is preferably in the range from approximately 14 to approximately 35 mm. Use of the invention in larger motors as well is, of course, not excluded. Fan 216 can be of any design, e.g. an axial, radial, or diagonal fan.

Rotor cup 224 has at its center a hub 230 in which is mounted, in thermally conductive fashion by plastic injection molding, a correspondingly shaped upper shaft end 232 of a rotor shaft 234 whose lower, free end is labeled 235.

Radial support of shaft 234 is provided by a plain bearing 236 that preferably is implemented as a double sintered bearing. Alternatively in the context of the invention, in order to achieve a particularly long service life, shaft 234 can also be supported using rolling bearings. Plain bearing 236 is mounted in a bearing tube 238 by being pressed in. Bearing tube 238 is preferably manufactured from steel, brass, or another suitable material. The use of a plastic is also not excluded. Bearing tube 238 is provided with a radial projection in the form of a flange 239, which in this example extends approximately perpendicular to rotation axis 241 of rotor 222. Internal stator 244 of motor 220 is mounted on the outer side of bearing tube 238 by being pressed on (cf. FIG. 4).

Sintered bearing 236 has a bulging portion 242 having a diameter that corresponds approximately to the diameter of a cylindrical portion of inner side 240 of bearing tube 238 and is dimensioned so that a tight fit results there upon assembly.

As depicted in FIG. 4, sintered bearing 236 has a lower plain bearing portion 248 and an upper plain bearing portion 250. This allows reliable support of shaft 234 and a corresponding long service life for motor 220 even at the high rotation speeds of these mini-fans, which are often in the range from 6,000 to 9,000 rpm.

Stator 244 has, in the usual fashion, a lamination stack 245 that is injection-embedded in a coil former 246 onto which a winding 247 is wound. Alternatively, stator 244 could also be implemented as a claw-pole stator.

Shaft 234 has, at its free end region 235, an annular groove or necked-down portion 258 into which elastic securing hooks 260 are latched after assembly. These hooks have a smaller axial extension than annular groove 258, and their function is principally to secure rotor 222 against being inadvertently pulled off.

Latching hooks 260 do not rest against shaft 234 at any point. They are implemented integrally with a cover (latching cover) 262, and are located on a lubricant repository 264 at whose bottom is a depression 266 in which a tracking cap 268 (FIG. 9) of shaft 234 rotates. Depression 266 can also be referred to as a "tracking cap cup." Depression 266 and tracking cap 268 together form an axial bearing for shaft 234.

As shown, for example, by FIG. 4, bearing tube 238 has in its upper region a hollow-cylindrical portion 240, and the latter widens toward the bottom in the manner of a truncated hollow cone 270 that transitions at the bottom into an approximately cylindrical portion 271 in which annular grooves 272, 273, having an approximately semicircular cross-section, are recessed (cf. FIG. 5). Cylindrical portion 271 widens toward the bottom in the manner of a truncated hollow cone 274. On its outer side, bearing tube 238 has, at the top, a cylindrical portion 275 onto which

internal stator 244 is pressed (cf. FIG. 4), and portion 275 transitions via a shoulder 276 into the upper side of flange 239. The latter forms, upon assembly, a stop for coil former 246, as depicted e.g. in FIG. 4. Underside 277 of flange 239 in turn transitions into a cylindrical portion 278 on the outer side of bearing tube 238. This portion 278 has a larger diameter than portion 275, and it continues into the cylindrical outer side 279 of latching cover 262, so that bearing tube 238 and latching cover 262 together form a cylindrical component that, as shown in FIG. 4, is implemented to be pressed into a cylindrical opening 280 of circuit board 217. This makes possible extremely simple assembly, but does require that, as shown in FIG. 4, an axial force  $F$  be generated in a downward direction on coil former 246, i.e. this assembly operation in opening 280 must be performed before rotor 262 is installed. The invention makes this readily possible; i.e. firstly, as shown in FIG. 4, internal stator 244 is pressed into opening 280 in the direction of an arrow 282, and then, as shown in FIG. 9, the motor is completed by the insertion of rotor 222.

As depicted in FIG. 5, latching cover 262 has on its outer side 283 latch ridges 284, 285 that are depicted only in this enlarged depiction. When latching cover 262 is pressed into opening 271 with a press fit, these ridges 284, 285 create a slight latching effect and at the same time constitute an excellent seal, so that no lubricant can run out of repository 264. The plastic used for cover 262 is sufficiently heat-resistant that it is not damaged by passing through a solder bath.

Four wire pins 288, to which terminals 290 of winding 247 are connected, are mounted in coil former 246 at regular 90-degree intervals. For the passage of these pins 288, flange 239 has either the shape according to FIG. 6 with four radial grooves 292, or the shape 239' shown in FIG. 7. Circuit board 217 has corresponding holes 294 into which these wire pins 288 are inserted during assembly and then soldered in a solder bath using a solder 296, which rises upward through hole 294 by capillary action and also solders terminal 290 to pin 288. This solder 296 then constitutes simultaneously the electrical connection and a mechanical joint between internal stator 244 and circuit board 217. This is possible because the weight of such a mini-fan is, for example, only 20 g.

The circulation of the lubricant corresponds to what is depicted in FIG. 2, and will therefore not be repeated. Hub 230 has, at its lower (in FIG. 9) end, an undercut 312 that throws the lubricant outward. Bearing tube 238 likewise has, at its upper end on the inner side, an undercut 314 that prevents lubricant from leaking out of fan 216 when the latter is in a tilted position. For this reason, gap 316 between bearing tube 238 and rotor 222 is also very narrow and is dimensioned in the manner of a capillary gap, in order to prevent lubricant from emerging. Lubricant thrown outward from undercut 312 flows along inner wall 240 of bearing tube 238 down to sintered bearing 236, and through the latter farther down into reservoir 264. The result of this is that a sufficient supply of lubricant is always present in reservoir 264 and in its depression 266.

#### ASSEMBLY

As shown in FIG. 4, firstly cylindrical part 271, 279 of bearing tube 238 is pressed into opening 280 of circuit board 217, resulting in the picture shown in FIG. 9. In this state, circuit board 217 is soldered in a solder bath in the usual fashion.

Then, as shown in FIG. 9, rotor 222 is mated to internal stator 244; in this context, as shown in FIG. 10, safety members 260 are firstly deflected outward and then snap into annular groove 258 of rotor shaft 234, thus preventing rotor 222 from being pulled out again. To eliminate friction losses (a very important consideration with these very small motors), safety members 260 are not in contact against annular groove 258.

For transport, rotors 222 can be transported separately and then installed on site, appropriate lubricant having previously been introduced into repository 264, 266. Transport with rotors 222 assembled is, however, also possible.

Because magnet 228, as depicted in FIG. 10, is not arranged symmetrically with respect to stator laminations 245 in terms of the axial direction of motor 220, but instead is offset upward with respect to them, a magnetic force acts on rotor 222 in a downward direction, pressing tracking cap 268 into depression 266.

Subsequent to assembly, fan 216 is tested in the usual way. Commutation can be accomplished, for example, by means of induced voltage, for which purpose a corresponding sensor coil is then provided; or a semiconductor sensor that senses the position of rotor 222 is used. Such matters are within the discretion of one skilled in the art. Many variants and modifications are of course possible within the scope of the present invention.